

METHOD FOR AUTOMATIC ANALYSIS OF ELECTRON BEAM DIFFRACTION PATTERN

BACKGROUND OF THE INVENTION

This invention relates to a method for automatic analysis of electron beam diffraction pattern in a transmission electron microscope.

A transmission electron microscope capable of displaying electron beam diffraction pattern is very useful for investigation of a crystalline specimen. An electron beam diffraction pattern contains information on the crystal structure of the specimen, its orientation and many others. Analysis of the diffraction pattern, therefore, makes it possible to precisely analyze the crystal structure of the specimen, to identify the specimen materials, and to determine the orientations. The conventional analysis procedures for electron beam diffraction patterns are carried out as follows. First, the diffraction pattern displayed on the diffraction pattern forming plane or on the screen of a cathode-ray tube (CRT) is photographed on a film, and the film is developed in a darkroom. Then, the position of each diffraction spot or radius of each ring in the diffraction pattern on the developed negative film is measured so as to calculate the d-values (i.e., lattice spacing) of the crystal. The calculated d-values are collated with the many cards (or a data table) recording the d-values corresponding to the various materials, so as to select the one card which closely coincides with the obtained set of d-values of the unknown crystalline material. As a result, the specimen material is identified, and orientation of the crystalline specimen is decided. These analysis procedures, however, required troublesome manual operation such as photographic processing in a darkroom. In addition, specialized knowledge about analysis of crystal structure is required.

SUMMARY OF THE INVENTION

The main object of the invention is to provide a method for automatic analysis of a diffraction pattern in a transmission electron microscope.

This invention is based on the following consideration for the characteristics of the electron beam diffraction pattern.

The electron beam diffraction pattern may present a spot- or ring-shaped appearance as shown in FIGS. 1(a) and (b), or a mixed appearance of both as shown in FIG. 1(c). The image processing for each appearance is different from each other. Accordingly, for automatic analysis of the diffraction pattern, it is necessary to decide on the appearance of the pattern on the basis of the results of image processing, whereas the appearance of the pattern to be analyzed is easily decided on by a glance at manual analysis.

In automatic analysis of the diffraction pattern according to this invention, the pattern forming plane is divided into many pixels (picture elements) and the electron beam intensity "I" at each pixel is measured and stored (together with the address of the pixel) in a frame memory forming part of internal memory means of the computer 4. In the graph shown in FIG. 2, the abscissa indicates the electron beam (or detected signal) intensity "I", and the ordinate indicates the frequency distribution H(I) respectively, where the frequency distribution (or histogram function) H(I) means the number of pixels having the same intensity "I". The curves "S", "R" and "SR" in FIG. 2 indicate the spot-shaped ap-

pearance, ring-shaped appearance and mixed appearance respectively, and the curve "B" indicates the background component of the three curves "S", "R" and "SR". It is apparent from FIG. 2 that the ratio of the number of pixels having high electron beam intensity to the total number of pixels corresponding to each appearance of the pattern is different with respect to each other. Accordingly, it is possible to decide on the appearance of the pattern on the basis of the difference in the frequency distribution "H" at the high electron beam intensity "I". For example, the δ -value indicated by the following equation (1) is calculated for a value indicating the shape of the frequency distribution curve, particularly in high electron beam intensity, as shown in FIG. 2

$$\delta = H(I) \cdot (I - \bar{I})^2 \quad (1)$$

where " \bar{I} " is the weighted average indicated by the following equation (2).

$$\bar{I} = \{ \Sigma H(I) \cdot I / \Sigma H(I) \} \quad (2)$$

And the appearance of the analyzed diffraction pattern is decided according to a predetermined value range, to which the calculated δ -value belongs. Furthermore, it is possible to change term $(I - \bar{I})^2$ in equation (1) to term $(I - \bar{I})^3$.

Automatic analysis of the invention based on the above mentioned consideration comprises the following steps:

- (a) A step for converting an electron beam diffraction pattern to a distribution data of electron beam intensity at each one of the pixels on which the diffraction pattern is formed,
- (b) A step for measuring frequency distribution of said electron beam intensity from said distribution data,
- (c) A step for deciding whether said diffraction pattern is composed of only diffraction spots, only diffraction rings, or diffraction spots and rings, on the basis of the data processing using said frequency distribution of said electron beam intensity,
- (d) A step for accumulating the lattice spacing d-value corresponding to each diffraction spot or ring appearing in a distribution data of electron beam intensity, and
- (e) A step for determining the specimen material corresponding to said diffraction pattern by collating said lattice spacing d-values with the d-values of the various materials in a crystal database.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1(a-c) a schematic drawings showing the three appearances of the electron beam diffraction patterns,

FIG. 2 is a graph showing the frequency distribution curve of the intensity at each one of the pixels on which an electron diffraction pattern is formed,

FIG. 3 is a schematic drawing showing one embodiment for carrying out the automatic analysis of the diffraction pattern according to this invention,

FIGS. 4, 5, 6, 7, and 10 are the flow charts for carrying out the automatic analysis according to this invention,

FIGS. 8, 9 (a-c) and 11 are schematic diagrams showing X or Y axis projection curves of the frequency distribution,

FIGS. 12(a-b) are a schematic diagrams for explaining the memorized crystal database, and